PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project	
Survival Estimates for the Passage of Juvenile Salmonids Through Dams and Reservoirs	
BPA project number	**9302900**
Contract renewal date (mm/yyyy)	**04/1999**
Multiple actions? (indicate Yes or No)	
Business name of agency, institution or organization requesting funding	
National Marine Fisheries Service	
Business acronym (if appropriate)	**NMFS/NWFSC**
Proposal contact person or principal investigator:	
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NPPC Program Measure Number(s) which this project addresses	
5.0F, 5.8A.8	
FWS/NMFS Biological Opinion Number(s) which this project addresses	
NMFS BO RPA Sec. 13f	
Other planning document references	
NMFS RP 2.1.d.3.	
Short description	
Provide precise measurements of survival of juvenile salmon as they pass through dams and reservoirs in the Snake and Columbia Rivers	
Target species	
Chinook salmon (yearling spring/summer and subyearling fall) and steelhead	

Section 2. Sorting and evaluation

Subbasin
Mainstem

Evaluation Process Sort

CBFWA caucus		CBFWA eval. process		ISRP project type	
X one or more caucus		If your project fits either of these processes, X one or both		X one or more categories	
X	Anadromous fish	X	Multi-year (milestone-based evaluation)		Watershed councils/model watersheds
	Resident Fish		Watershed project eval.		Information dissemination
	Wildlife				Operation & maintenance
					New construction

		X	Research & monitoring
			Implementation & mgmt
			Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
91-029	Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River Basin	We began working cooperatively with this project in 1995 to estimate survival for hatchery-reared and wild subyearling fall chinook salmon through free-flowing sections, reservoirs, and dams of the Snake River.
96-006	PATH	Our study provides critical empirical data used for modeling survival through the hydrosystem in PATH.
91-051	Monitoring and evaluation statistical support	Our study provides many of the PIT-tagged fish used in their analysis.
83-319	New fish tag system	We continue to rely on this project to provide the innovations needed to conduct multiple-recapture survival studies in the Snake and Columbia Rivers in a variety of habitats. We provide feedback to the project on the performance of many of their innovations.
83-323	Smolt condition and arrival timing at Lower Granite Dam	We estimate survival for PIT-tagged fish released from Snake River Basin traps in this study through the Snake River.
96-020	Comparative survival rate study of hatchery PIT tagged chinook	We utilize fish PIT-tagged from this study to estimate survival from hatcheries through the Snake River.
94-034	Assessing summer/fall chinook restoration in the Snake River Basin	We began working cooperatively with this project in 1996 to estimate survival for hatchery-reared subyearling fall chinook salmon released in the Clearwater River.

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1993	Successfully captured, PIT-tagged, and released targeted numbers of yearling chinook salmon to estimate survival through dams and reservoirs for the first time since the 1980.'s	Yes.
1994	Added juvenile steelhead to the study and an	Yes

	additional reach (Little Goose Dam to Lower Monumental Dam).	
1995	Added subyearling fall chinook salmon to the study.	Yes
1996	Added additional reaches (Lower Monumental Dam to McNary Dam and McNary Dam to John Day Dam).	Yes

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Provide annual estimates of survival for spring-migrating juvenile salmonids through Snake and Columbia River dams and reservoirs	a	PIT-tag and release juvenile salmonids at Lower Granite Dam.
		b	Estimate detection and survival probabilities (with standard errors) for above releases.
		c	Estimate survival for PIT-tagged fish released in other studies in the basin (hatcheries, traps, etc.)
2	Estimate survival through longer reaches of the Snake and Columbia Rivers	a	Evaluate post-detection bypass survival at new PIT tag facilities.
		b	Determine effects of new PIT tag interrogation facilities on sample size requirements for PIT tag studies conducted upstream.
		c	Explore use of additional PIT tag detection sites (such as PIT tag towed array system, recoveries from Rice Island bird colonies) in survival estimation.
3	Partition mortality between release at hatcheries (and natal streams for wild fish) and the head of Lower Granite Reservoir	a	Deploy a series of streambed flat-plate PIT tag detectors in tributaries above Lower Granite Reservoir.
		b	Estimate survival through tributaries for wild and hatchery fish.
4	Estimate survival of subyearling fall chinook salmon migrating through the Snake and Columbia Rivers	a	Release PIT-tagged Lyons Ferry Hatchery subyearling fall chinook salmon into the free-flowing Snake and Clearwater Rivers.
		b	Estimate their survival through the Snake River and compare to estimates of survival for wild migrants in this reach.
		c	PIT tag and release river-run (mostly wild) fall chinook salmon at McNary Dam in the bypass system and tailrace.
		d	Estimate their survival through the bypass system at McNary Dam and through the Lower Columbia River.
5	Explore relationships between smolt survival through the Snake and Columbia Rivers and flow, travel time, and dam operations using a long-term data set	a	Correlate survival estimates with flow, travel time, temperature, turbidity, and dam operations for individual years and over multiple years.

Objective schedules and costs

	Start date	End date	Measureable biological	Milestone	FY2000

Obj #	mm/yyyy	mm/yyyy	objective(s)		Cost %
1	03/1993	12/2015			15
2	03/1994	12/2015			10
3	03/1996	12/2015			35
4	05/1995	12/2015			35
5	03/1993	12/2015			5
				Total	100

Schedule constraints

Objective 3 dependent on development of streambed flat-plate PIT tag detector by Project 83-319.

Completion date

We would expect this project to continue at some level into the future to evaluate changes in juvenile salmonid survival due to alterations in the hydropower system and it's operation.

Section 5. Budget

FY99 project budget (BPA obligated):	**$1,081,000**

FY2000 budget by line item

Item	Note	% of total	FY2000 ($)
Personnel			208,200
Fringe benefits			99,700
Supplies, materials, non-expendable property			65,600
Operations & maintenance			5,400
Capital acquisitions or improvements (e.g. land, buildings, major equip.)	Streambed flat-plate PIT tag detectors (number dependent on cost and performance).		160,000
NEPA costs			0
Construction-related support			0
PIT tags	# of tags: 85,500		247,950
Travel			105,700
Indirect costs			146,400
Subcontractor	University of Washington		100,000
	Pacific States Marine Fisheries Commission		60,000
Other			0
		TOTAL BPA REQUESTED BUDGET	1,198,950

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
		Total project cost (including BPA portion)	

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	1,200,000	1,200,000	1,200,000	1,200,000

Section 6. References

Watershed?	Reference

PART II - NARRATIVE

Section 7. Abstract

The goal of this study is to provide up-to-date, precise estimates of survival of juvenile salmonids migrating through reservoirs, dams, and free-flowing reaches of the Snake and Columbia Rivers. This information is critical in determining strategies to recover depressed stocks.

To accomplish this goal, we will continue to PIT tag yearling chinook salmon and steelhead at Lower Granite Dam as needed to estimate their survival through the hydropower system. When possible, we will utilize fish PIT-tagged in other studies to reduce tagging needed specifically for our study. We will also continue to PIT tag hatchery subyearling fall chinook salmon for release above Lower Granite Dam to estimate their survival through the Snake River and PIT tag and release river-run subyearling fall chinook salmon (mostly wild Handford stock) at McNary Dam to estimate their survival through the lower Columbia River. As the PIT-tag system expands on the Columbia River, we will estimate survival over longer reaches of the hydropower system. We will determine where losses and delay occur for yearling chinook salmon between the hatchery or natal streams (for wild fish) and the head of Lower Granite Reservoir using a series of streambed flat-plate PIT tag detectors deployed in tributaries. We will also explore the relationships among survival, travel time, environmental variables, and dam operations using the expanding data base generated by this study.

Section 8. Project description

a. Technical and/or scientific background

Hydrosystem mortality estimates in the 1970s (Raymond 1979, Sims and Ossiander 1981) were derived from studies in a river system that differs considerably from that which exists today (Williams and Matthews 1995). The magnitude, locations, and causes of smolt mortality under present passage conditions must be quantified accurately and precisely. Until this accomplished, our ability to develop corrective measures and to assess their effects will be limited. Studies to estimate survival of juvenile salmonids migrating through the Snake and Columbia River hydrosystem, and the relationship between survival and environmental conditions are called for in the NMFS 1994 Biological Opinion, NPPC 1994 Fish and Wildlife Plan, and the NMFS Recovery Plan.

Recent advances in fish-marking technologies (e.g., Passive Integrated Transponder (PIT) tags, "balloon tags," and miniature radiotransmitter tags) and statistical methodology have provided new approaches for the design and analysis of smolt passage studies. Burnham et al. (1987) proposed models for paired release-recapture data [hereafter referred to as Paired-Release (PR) Models] that appeared appropriate for the estimation of survival through hydroelectric projects via turbines, bypasses, or spill. Valid estimation of survival in longer stretches of river (reservoirs and free-flowing river sections) has been more problematic, because the PR Model assumption of mixing and simultaneous downstream movement of reference and test groups is difficult to satisfy when release locations are farther apart.

Hoffmann and Skalski (in Dauble et al. 1993) demonstrated how release-recapture models proposed by Cormack (1964), Jolly (1965), and Seber (1965) may be applied to single release groups of PIT-tagged fish. The Cormack model is hereafter referred to as the Single-Release (SR) Model. However, Hoffmann and Skalski also showed that survival estimates based on the SR Model were biased when mortality occurred in juvenile bypass systems after the fish were detected (i.e., after detection but before remixing with non-bypassed fish). The Modified

Single-Release (MSR) Model (Dauble et al. 1993) was proposed to correct for this bias. Satisfying the assumptions of the SR and MSR models appeared easier than those of the PR Model, thus making precise quantitative measures of survival possible.

Beginning in 1993, the National Marine Fisheries Service (NMFS) and the University of Washington (UW) conducted research to determine survival and travel-time characteristics of wild and hatchery-reared spring/summer chinook salmon and hatchery steelhead migrating through Snake River dams and reservoirs (Iwamoto et al. 1994, Muir et al. 1995, 1996, Smith et al. 1997, Skalski et al. 1998). The goals of this research program were to 1) field test and evaluate the Single-Release, Modified Single-Release, and Paired-Release Models for the estimation of reach and project survival, 2) identify operational and logistical constraints to their execution, 3) determine their usefulness in providing precise estimates of reach and project survival, and 4) obtain baseline survival and travel time estimates. In 1995, a pilot study was initiated using hatchery-reared subyearling fall chinook salmon to estimate their survival through these same reaches. To a large extent, the objectives, techniques, and analyses have been the same for all species.

The research from 1993 through 1998 has shown that the field techniques to collect and PIT tag fish, and statistical methodologies to analyze multiple downstream detections of PIT-tagged fish are sound and result in accurate and precise survival and travel-time estimates. Estimates of survival for yearling chinook salmon and steelhead have generally been higher than expected before the beginning of the study, averaging about 90% or greater per reservoir/dam combination each year and have generally been increasing each year as incremental improvements have been made to the hydropower system and its operation. Survival estimates for PIT-tagged smolts released from hatcheries upstream from Lower Granite Dam were also calculated each year. Survival probability estimates to Lower Granite Dam tailrace for hatchery releases were much lower than for our releases at the head of Lower Granite Reservoir and were generally inversely proportional to migration distance. Efforts began in 1997 using miniature radio tags to determine where and why this mortality above Lower Granite Reservoir occurs.

Estimates of survival for hatchery subyearling fall chinook salmon have been much lower than for spring migrants, both from their release above Lower Granite Reservoir to Lower Granite Dam, and in the reaches downstream between dams.

b. Rationale and significance to Regional Programs

This study (Objective 5) addresses needs identified in the 1994 FWP (Juvenile Salmon Migration, Research and Monitoring Section 5.0F), for a better understanding of the relationship between spring and summer flow velocity and survival. The FWP states: "The Council joins with the National Marine Fisheries Service and other regional interests in insisting that these relationships immediately receive the highest priority in the region's research efforts". This study (Objective 3) also addresses Section 5.8A8 which states: "Continue to conduct research on the survival of hatchery, wild, and naturally spawning chinook salmon from headwater production areas to mainstem transport sites to determine the extent of mortality prior to transportation."

The 1995 NMFS Biological Opinion (Section 13f, Reasonable and Prudent Alternatives) states: "The BPA shall evaluate juvenile survival during downstream migration and desired levels of flow augmentation. The NMFS, in cooperation with other agencies and entities, shall formulate long-range survival studies to determine within-year and between-year survival of smolts migrating through reservoirs and past dams with various flows, spills, and bypass configurations. Studies will relate survival to varying river flows, spills and dam operations. As an offshoot of the research, studies will be designed to update or confirm relationships of migration rates of fish to flow in the river. Further, where feasible, researchers will determine relationships of fish survival to migrational timing."

Clearly, this study addresses needs outlined in the 1994 NPPC FWP and the NMFS FCRPS Biological Opinion by providing annual estimates of smolt survival and their relationship with environmental conditions and hydrosystem operations. This study has complemented other studies in the basin by estimating survival for PIT-tagged smolts released by other researchers (i.e., transportation evaluation, Idaho PIT tag study, releases from hatcheries and trap sites). Utilizing PIT-tagged fish from these other studies has greatly reduced the numbers of fish needed for our tagging each year.

c. Relationships to other projects

This study complements studies we are conducting at Snake River Dams (COE funded) that evaluate survival for yearling chinook salmon and steelhead passing through turbines, spillways, or bypass systems. By combining estimates of passage route survival (COE studies) with our estimates of reach survival and detection probability (BPA 93-029), we are able to provide estimates of overall project survival, reservoir survival, spill efficiency, and spill effectiveness at Snake River dams in some years (Muir et al. 1998).

Study 93-029 also estimates survival for yearling chinook salmon released at Lower Granite Dam to evaluate transportation (COE Project E8690103). In years the transport study is conducted, we rely on the control fish released at Lower Granite Dam to estimate survival through the hydrosystem instead of tagging our own fish for this purpose.

We began cooperative studies with the USFWS (91-029) and the Nez Perce Tribe (94-034) to estimate detection probabilities at Snake River Dams and survival of subyearling fall chinook salmon through the Snake River. Together, we PIT tag hatchery fish from Lyons Ferry Hatchery and release them above Lower Granite Dam to evaluate restoration and supplementation strategies to recover these stocks.

We provide estimates of survival for PIT-tagged fish released from other studies including hatcheries (96-020), traps (83-323), and various other studies as requested. We also provide both empirical data and statistical support to other efforts including PATH (96-006) and Monitoring and Evaluation Statistical Support (91-051).

This project works collaboratively with project 83-319 (New Fish Tag System) by requesting modifications to the existing PIT-tag system or creation of new systems (slide gates in bypass systems, sort-by-code systems, streambed flat-plate detector systems) to estimate survival through dams, reservoirs, and free-flowing reaches of the basin.

Personnel from this project frequently provide technical advice on study design and statistical analysis to other researchers conducting PIT-tag studies in the basin.

d. Project history (for ongoing projects)

Results Achieved

During the first year of this study (1993), seven groups of yearling chinook salmon were purse-seined near the head of Lower Granite Reservoir, PIT-tagged, and released to evaluate the suitability of the Snake River PIT-tag interrogation and slide-gate systems and the SR and MSR Models for estimating survival through the Snake River. Additional releases were made at Lower Granite and Little Goose Dams to evaluate post-detection bypass survival (testing a model assumption), turbine survival, and spillway survival (at Little Goose Dam only). The study plan was successfully executed resulting in estimates of survival for yearling chinook salmon from the head of Lower Granite Reservoir to the tailraces of Lower Granite and Little Goose Dams. Estimates of survival for turbine and spillway passage were also obtained as well as estimates of survival for releases of PIT-tagged salmonids from Snake River Basin hatcheries and trap sites.

Results from 1994 and 1995 included survival estimates from the head of Lower Granite Reservoir for yearling chinook salmon purse-seined, PIT-tagged, and released over a greater portion of the migration, survival estimates for purse-seined hatchery steelhead, and survival through an additional reach, from Little Goose Dam to Lower Monumental Dam tailrace. Paired releases were also made at Lower Granite, Little Goose, and Lower Monumental Dams to estimate post-detection bypass and turbine survival. Survival was also estimated for releases of PIT-tagged fish from Snake River Basin hatcheries and trap sites.

During 1995, large numbers of PIT-tagged yearling chinook salmon were released in the tailrace at Lower Granite Dam to evaluate transportation. This permitted estimation of survival through an additional reach, from Lower Monumental Dam tailrace to McNary Dam tailrace (through 2 dams and reservoirs). We also provided estimates of survival for hatchery subyearling fall chinook salmon migrating through the Snake River in 1995 by transporting PIT-tagged Lyons Ferry Hatchery fish upstream and releasing them.

In 1996, we began efforts to determine where mortality occurs upstream above Lower Granite Reservoir by releasing PIT-tagged yearling chinook salmon captured by beach seine in the free-flowing Snake River above Asotin, Washington. We also provided estimates of survival through each of the downstream reaches to the tailrace of Lower Monumental Dam and, for yearling chinook salmon, to the tailrace of McNary Dam, as well as estimates of survival for PIT-tagged fish from Snake River Basin hatcheries and trap sites. In our 1996 annual report, we explored relationships between smolt survival through the Snake and Columbia Rivers and flow, travel time, and dam operations using the estimates of survival obtained from 1993 through 1996. We also continued our releases of PIT-tagged Lyons Ferry Hatchery subyearling fall chinook salmon above Lower Granite Dam.

In 1997 and 1998, we continued efforts to partition where mortality occurs upstream above Lower Granite Reservoir by releasing PIT-tagged/radio-tagged (combination tag) yearling chinook salmon at Lookingglass Hatchery and monitoring their behavior, travel time, and survival downstream to the head of Lower Granite Reservoir. We also provided estimates of survival through each of the downstream reaches to the tailrace of McNary Dam for hatchery yearling chinook salmon (from the Idaho PIT tag study and NMFS Transportation studies at Lower Granite Dam) and steelhead (PIT-tagged and released by us at Lower Granite Dam), estimated survival through the bypass system at McNary Dam for yearling chinook salmon, and continued our releases of PIT-tagged Lyons Ferry Hatchery fall chinook salmon subyearlings above Lower Granite Dam.

Adaptive Management Implications

The survival estimation methods developed and tested in this study can be used to evaluate various management strategies for the Snake and Columbia Rivers such as drawdown, flow augmentation, or spill programs by comparing changes in survival within and across years. The paired-release methods can be used to evaluate structural modifications at the dams such as flow deflectors on spillways, surface bypass collectors, extended length screens, and changes in turbine operation.

Years Underway

This project began in 1993, and has continued to the present.

Past Costs

Project Reports and Technical Papers

Hockersmith, E. E., Smith, S. G., W. D. Muir, B. P. Sandford, J. G. Williams, and J. R. Skalski. 1998. Survival estimates for the passage of juvenile salmonids through Snake River dams and reservoirs, 1997. Annual report to Bonneville Power Administration, Portland, OR, Contract DE-AI79-93BP10891, Project 93-29 (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Iwamoto, R. N., W. D. Muir, B. P. Sandford, K. W. McIntyre, D. A. Frost, J. G. Williams, S. G. Smith, and J. R. Skalski. 1994. Survival estimates for the passage of juvenile chinook salmon through Snake River dams and reservoirs, 1993. Annual report to Bonneville Power Administration, Portland, OR, Contract DE-AI79-93BP10891, Project 93-29, 140 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Muir, W. D., S. G. Smith, R. N. Iwamoto, D. J. Kamikawa, K. W. McIntyre, E. E. Hockersmith, B. P. Sandford, P. A. Ocker, T. E. Ruehle, J. G. Williams, and J. R. Skalski. 1995. Survival estimates for the passage of juvenile salmonids through Snake River dams and reservoirs, 1994. Annual report to Bonneville Power Administration, Portland, OR, Contract DE-AI79-93BP10891, Project 93-29, and U.S. Army Corps of Engineers, Walla Walla, WA, Project E86940119, 187 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Muir, W. D., S. G. Smith, E. E. Hockersmith, S. Achord, R. F. Absolon, P. A. Ocker, B. M. Eppard, T. E. Ruehle, J. G. Williams, R. N. Iwamoto, and J. R. Skalski. 1996. Survival estimates for the passage of yearling chinook salmon and steelhead through Snake River dams and reservoirs, 1995. Annual report to Bonneville Power Administration, Portland, OR, Contract DE-AI79-93BP10891, Project 93-29, and U.S. Army Corps of Engineers, Walla Walla, WA, Project E86940119, 150 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Muir, W. D., S. G. Smith, E. E. Hockersmith, M. B. Eppard, W. P. Conner, and B. D. Arnsberg. 1998. Passage survival of hatchery subyearling fall chinook salmon to Lower Granite, Little Goose, and Lower Monumental dams, 1996. Pages **1-65** *In* J.G. Williams and T. C. Bjornn, editors. Fall chinook salmon survival and supplementation studies in the Snake and Lower Snake River Reservoirs, 1995. Annual report to Bonneville Power Administration, Portland, OR, Project 93-029. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Smith, S. G., W. D. Muir, E. E. Hockersmith, M. B. Eppard, and W. P. Connor. 1997. Passage survival of natural and hatchery subyearling fall chinook salmon to Lower Granite, Little Goose, and Lower Monumental Dams. Pages 1-65 *In* J.G. Williams and T. C. Bjornn, editors. Fall chinook salmon survival and supplementation studies in the Snake and Lower Snake River Reservoirs, 1995. Annual report to Bonneville Power Administration, Portland, OR, Project 93-029, and U.S. Army Corps of Engineers, Walla Walla, WA. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Smith, S. G., W. D. Muir, E. E. Hockersmith, S. Achord, M. B. Eppard, T. E. Ruehle, J. G. Williams, and J. R. Skalski. 1998. Survival estimates for the passage of juvenile salmonids through Snake River dams and reservoirs, 1996. Annual report to Bonneville Power Administration, Portland, OR, Contract DE-

AI79-93BP10891, Project 93-29 (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Skalski, J. R., S. G. Smith, R. N. Iwamoto, J. G. Williams, and A. Hoffmann. 1998. Use of PIT-tags to estimate survival of migrating juvenile salmonids in the Snake and Columbia Rivers. Can. J. Fish. Aquat. Sci. 55:1484-1493.

e. Proposal objectives

Objective 1. Provide annual estimates of survival for spring-migrating juvenile salmonids through Snake and Columbia River dams and reservoirs.

Annual estimates of survival will be provided to the region to help determine the effectiveness of management strategies used to improve survival for juvenile salmonids migrating through the Snake and Columbia Rivers. Estimates will be provided first in the form of a memorandum followed by a more in-depth annual report an/or publications.

Objective 2. Estimate survival through longer reaches of the Snake and Columbia Rivers.

As PIT-tag interrogation systems come on line at dams farther downstream, survival will be estimated through longer reaches of the Snake and Columbia Rivers. Additional interrogation sites downstream must be evaluated to determine the extent of post-detection bypass mortality, if any. This information will be provided in the form of a memorandum followed by a more in-depth annual report.

Objective 3. Partition mortality between release at hatcheries (and natal streams for wild fish) and the head of Lower Granite Reservoir.

Comparison of survival estimates for releases from Snake River Basin hatcheries, trap sites, and fish purse-seined and released at the head of Lower Granite Reservoir indicate a great deal of smolt mortality occurs upstream from the hydropower system. Partitioning where and when this mortality occurs might allow us to determine the causes of mortality so corrective action could be taken to improve survival. This information will be provided in the form of a memorandum followed by a more in-depth annual report and/or publications.

Objective 4. Estimate survival of subyearling fall chinook salmon migrating through the Snake and Columbia Rivers.

Information on survival and travel time for subyearling fall chinook salmon migrating through the Snake and Columbia Rivers are needed to make management decisions to maximize their survival. Because too few natural fish are available in the Snake River to make reliable estimates of survival each year, hatchery subyearlings are used as surrogates and their performance compared to natural migrants. In the lower Columbia River, river-run fish (mostly wild Handford stock) will be used. This information will be provided in the form of a memorandum followed by a more in-depth annual report.

Objective 5. Explore relationships between smolt survival through the Snake and Columbia Rivers and flow, travel time, and dam operations using a long-term data set.

Under this objective, we will test the following hypothesis:

Ho1: The effects of environmental conditions (e.g., flow, water temperature, turbidity) have no influence on smolt survival through the Snake River.
If rejected, alternate hypotheses are that one or more of these factors do influence smolt survival.

Ho2: The effects of project operations (e.g., increased spill, reservoir drawdown) have no influence on smolt survival through the Snake River.
If rejected, alternate hypotheses are that some of these factors do influence smolt survival.

Ho3: The effects of project improvements (e.g., installation of surface collectors, extended length screens, changes in turbines and bypass systems) have no influence on smolt survival through the Snake River.
If rejected, alternate hypotheses are that some of these factors do influence smolt survival.

This information will be provided in annual reports and/or peer reviewed publications.

f. Methods

Scope

In 2000, we plan to continue providing reach and project survival estimates through Snake and Columbia River dams and reservoirs throughout the yearling chinook salmon, subyearling chinook salmon, and hatchery steelhead migrations. To reduce the numbers of fish needed for PIT-tagging, we will rely on releases of PIT-tagged yearling chinook salmon from hatcheries (Idaho PIT tag Study and other hatchery studies) and Lower Granite Dam (Transport Evaluation) to estimate survival through the Snake River if those studies are conducted. If they are not, we will collect, PIT-tag, and release hatchery steelhead and yearling chinook salmon at Lower Granite Dam. We will evaluate survival through the bypass systems at McNary and John Day Dams to estimate the amount of post-detection bypass mortality (testing an assumption of the SR Model) that occurs, and evaluate other passage routes at those dams if needed. We will also continue our efforts to determine where and when mortality occurs for yearling chinook salmon between release from Snake River Basin hatcheries and arrival at the head of Lower Granite Reservoir using PIT tags and streambed flat-plate detectors. We will also continue releasing PIT-tagged hatchery subyearling fall chinook salmon above Lower Granite Reservoir and river-run fish at McNary Dam to estimate survival during the summer.

Approach

Approximately 30,000 hatchery steelhead will be collected, tagged, and released at Lower Granite Dam in proportion to their arrival timing. A similar number of hatchery yearling chinook salmon will also be tagged there if sufficient numbers of smolts are not PIT-tagged for other studies in 2000 (Idaho PIT tag Study or Transport Evaluation Study).

We will evaluate post-detection bypass survival at either McNary or John Day Dams during 2000 by making paired releases of hatchery steelhead, hatchery yearling chinook salmon, or river-run subyearling fall chinook salmon, with the releases consisting of a bypass release (made in front of the intake screen) and a tailrace release.

To partition yearling chinook salmon mortality from release at the hatchery, or for wild fish, from their natal stream to Lower Granite Dam, we will deploy a series of streambed flat-plate PIT tag detectors in tributaries. Travel time and survival will be estimated between detectors during downstream migration using the same statistical models used to estimate survival through downstream reaches.

To estimate survival for subyearling fall chinook salmon, we will PIT tag approximately 15,000 fish at Lyons Ferry Hatchery, transport them to release sites in the free-flowing Snake River (Pittsburg Landing and Billy Creek) and the Clearwater River (Big Canyon Creek) and release them after short-term acclimation each week from the end of May until the end of June. At McNary Dam, we will PIT tag and release river-run (mostly wild) subyearling fall chinook salmon during their migration to estimate their survival through the lower Columbia River.

Detailed Methodology

Objective 1. Provide annual estimates of survival for spring-migrating juvenile salmonids through Snake and Columbia River dams and reservoirs.

Task a. PIT tag and release juvenile salmonids at Lower Granite Dam.

Primary releases will be made in the tailrace at Lower Granite Dam. The collection period will encompass the major portion of the spring migration (6 to 7 weeks) to measure variability through time and to investigate possible relationships between survival and environmental conditions that may vary throughout the season. The number of fish to tag of each species will be determined by numbers being tagged upstream and at Lower Granite Dam in other studies.

Primary release groups will be composed of a total of approximately 30,000 hatchery-reared steelhead collected at the Lower Granite Dam juvenile collection facility in proportion to their arrival timing at the dam, with a similar number of hatchery yearling chinook salmon also collected if sufficient numbers are not PIT-tagged in other studies. Only hatchery-reared fish, identifiable by the absence of adipose or ventral fins, will be used. Fish-handling methods such as water-to-water transfers and pre-anesthesia will minimize damage and stress to fish during the collection and sorting process. We will hand-inject PIT tags, using pre-established techniques (Iwamoto et al. 1994), using the NMFS transportation marking facility at Lower Granite Dam. Tagging personnel will be supervised by experienced NMFS employees. PIT-tagged fish will be allowed to recover for at least 24 hours. Mortalities will be recorded and removed prior to release. We will release PIT-tagged fish 5 days per week as long as fish are available.

Task b. Estimate detection probabilities and survivals (with standard errors) for above releases.

Detection data for primary release groups will be collected at Little Goose, Lower Monumental, McNary, John Day, and Bonneville Dams for fish that are guided into the bypass facilities and interrogated. The majority of detected fish will be returned to the river at all dams. Detection at multiple downstream sites increases the ability to

test assumptions of the SR Model (e.g., that detected and non-detected fish at a dam have equal probabilities of survival and detection at subsequent detection facilities) and precision.

Detection histories for fish of primary release groups will be analyzed to provide estimates and confidence limits for survival probabilities in the following reaches: 1) from Lower Granite Dam tailrace to Little Goose Dam tailrace, 2) from Little Goose Dam tailrace to Lower Monumental Dam tailrace, 3) from Lower Monumental Dam tailrace to McNary Dam tailrace, and 4) from McNary Dam tailrace to John Day tailrace. The SR Model will be used to calculate survival estimates for the primary releases.

A statistical program developed at the University of Washington (Skalski et al. 1993, Smith et al. 1994) for analyzing release-recapture data will be used to perform all survival analyses. The program, named SURPH, for "Survival with Proportional Hazards," extends the standard Cormack (1964) and Jolly (1965)-Seber (1965) models to allow simultaneous analysis of release-recapture data from multiple release groups.

Task c. Estimate survival probabilities for fish released in other studies in the basin (hatcheries, trap, etc.).

We will provide estimates of survival for release groups of PIT-tagged hatchery yearling chinook salmon and steelhead from hatcheries and traps. We will recommend sample sizes and replicate numbers for releases of PIT-tagged fish from other locations, such as hatcheries or traps as requested.

Objective 2. Estimate survival through longer reaches of the Snake and Columbia Rivers.

Task a. Evaluate post-detection bypass survival at new PIT tag facilities.

Use of the SR Model to estimate reach survival requires that post-detection bypass mortality at detection sites (dams) in that reach be negligible. If not, the mortality must be quantified and the MSR Model used to estimate survival through that reach. To confidently use the SR Model for estimating survival through the additional reaches made possible by the new PIT tag facilities at John Day and McNary Dams will require that post-detection bypass survival be evaluated at both sites.

For these evaluations, fish will be collected at each dam, PIT-tagged, and released via 7.6 cm flexible hose into the collection channel, or released into the tailrace from tanks mounted on a boat. The tagging procedures will be the same as those described in Objective 1 with fish held in 1,300-L tanks for 24 hours prior to release. Replicated paired releases of each species at each dam will be made, with the number of fish in each replicate and the number of replicates determined after examining detection probabilities from releases of PIT-tagged fish in 1998.

Post-detection bypass survival will be estimated using the PR Model (Burnham et al. 1987) based on detections of PIT-tagged fish at downstream dams. Comparisons of downstream passage distributions will be made to ensure equal mixing of test and reference groups.

Task b. Determine effects of new PIT-tag interrogation facilities on sample size requirements for PIT tag studies conducted upstream.

New PIT-tag interrogation facilities or increased detection probabilities at existing downstream sites increase overall PIT tag detection probability for releases made upstream. This reduces the number of PIT-tagged fish needed to estimate survival while maintaining a particular level of precision, or increases the level of precision for the same release size. This information will be provided to interested researchers.

Task c. Explore use of additional PIT-tag detection sites (such as PIT-tag towed array system and recoveries from Rice Island bird colonies) in survival estimation.

PIT-tag detections from other sites such as the PIT-tag towed array used in the Columbia River Estuary and the mobile flat-plate detector used on the Rice Island caspian tern and cormorant colonies will be evaluated for use in survival estimation. Their use might allow survival estimation to the tailrace of Bonneville Dam and result in greater precision for estimates in upstream reaches.

Objective 3. Partition mortality between release at hatcheries (and natal streams for wild fish) and the head of Lower Granite Reservoir.

Task a. Deploy a series of streambed flat-plate PIT tag detectors in tributaries above Lower Granite Reservoir.

A series of flat-plate PIT tag detectors (to be developed by project 83-319) will be deployed in a selected tributary above Lower Granite Reservoir. The number of detectors used will depend on their cost and how well they

perform in initial testing. The tributary chosen will be one that has both wild PIT-tagged smolts (PIT-tagged as parr) and hatchery smolts (PIT-tagged at the hatchery) from other studies coming downstream.

Task b. Estimate survival through tributaries for wild and hatchery fish.

The SR Model will be used to estimate survival through tributaries using detection probabilities from individual streambed flat-plate detectors just as detection probabilites from PIT-tagged fish passing through individual dams are used in reach estimates through the Snake River. Capture histories for each PIT-tagged fish will be constructed and travel times between detectors calculated to determine areas where fish overwinter (wild parr) and delay during thier migration (both hatchery and wild smolts). Relationships among travel time, survival, and environmental variaibles in free-flowing reaches will also be explored.

Objective 4. Estimate survival of subyearling fall chinook salmon migrating through the Snake and Columbia Rivers.

Task a. Release PIT-tagged Lyons Ferry Hatchery subyearling fall chinook salmon into the free-flowing Snake and Clearwater Rivers.

Hatchery-reared subyearling fall chinook salmon will be released at Pittsburg Landing and Billy Creek in the free-flowing Snake River and Big Canyon Creek in the free-flowing Clearwater River. To investigate temporal variability of survival probabilities and travel time, the series of releases will be timed to encompass the major portion of the migration season for wild/natural subyearling fall chinook salmon; approximately a 5- to 6-week period beginning in late May. Fish will be PIT tagged at Lyons Ferry Hatchery, transported to release sites, acclimated in their transport trucks to ambient river water temperature, and released. Size at release of the experimental fish will approximate the size of wild/natural fall chinook salmon present in the river at Pittsburg Landing at the time of release.

Replicate numbers and release sizes are based on the results of the 1995 through 1998 studies and the desired precision. A variety of conditions and parameter values were used to calculate expected precision of the survival estimates and to determine the number of replicate releases and number of fish per release. Over a 6-week period beginning in late May, we plan to release 1,250 fish per week at each release site. For expected survival of 60% from point of release above Lower Granite Reservoir to Lower Granite Dam tailrace, we anticipate that 6 releases of 1,250 fish each will result in precision of approximately 0.044 (half-width of 95% confidence interval).

Task b. Estimate their survival through the Snake River and compare to estimates of survival for wild migrants in this reach.

Data processing, data quality assurance/control, and survival estimation methods will be identical to those for spring/summer chinook salmon and steelhead (see Objective 1). For each release, we will compute point estimates and confidence intervals for survival probabilities through each of the reaches. Travel time statistics will also be computed.

Task c. PIT tag and release river-run (mostly wild) fall chinook salmon at McNary Dam in the bypass system and tailrace.

River-run (mostly wild) subyearling fall chinook salmon will be PIT-tagged at McNary Dam's juvenile fish facility and released into the collection channel and tailrace. These releases will serve two purposes. First, they will provide an estimate of survival through the juvenile bypass facility at McNary Dam. To date, we have been unsuccessful at estimating bypass survival for subyearling fall chinook at Snake River dams due to insufficient numbers of fish available for release. This information is needed to test a SR Model assumption (post-detection bypass survival). Second, these releases will allow estimation of reach survival of subyearling fall chinook salmon in the lower Columbia River. Our releases of Lyons Ferry Hatchery subyearling fall chinook salmon in the Snake River have not been of sufficient size to estimate survival in the lower river. We will use the same tagging/release procedures as described in Objective 1. Sample sizes will depend on detection probabilities observed in 1999, number of PIT tags available, and expected flow volume.

Task d. Estimate their survival through the bypass system at McNary Dam and through the Lower Columbia River.

Detection histories for fish from bypass and tailrace release groups at McNary Dam will be analyzed to provide estimates and confidence limits for survival probabilities from McNary Dam tailrace to John Day tailrace and possibly from John Day Dam tailrace to Bonneville Dam tailrace (if sufficient numbers of PIT tagged fish are detected with either the PIT tag towed array or mobile flat-plate detector on Rice Island). The SR Model will be

used to calculate reach survival estimates for these releases and relative recoveries compared to estimate bypass survival.

Objective 5. Explore relationships between smolt survival through the Snake and Columbia Rivers and flow, travel time, and dam operations using a long-term data set.

Task a. Correlate survival estimates with flow, temperature, turbidity, travel time, and dam operations for individual years and over multiple years.

We will conduct correlation analysis with the survival estimates obtained each year with estimates of travel time for those fish and their exposure to environmental variables including flow, water temperature, turbidity, and dissolved gas exposure. We will access the environmental data from the internet site located at the University of Washington (DART) and/or the Fish Passage Center. Similar analysis will be performed using the survival estimates and environmental data from multiple years of the study.

References

(Project 93-029 reports and papers listed under Project Reports and Technical Papers section)

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Muir, W. D., S. G. Smith, K. V. McIntyre, and B. P. Sandford. 1998. Project survival of juvenile salmonids passing through the bypass system, turbines, and spillways with and without flow deflectors at Little Goose Dam, 1997. Report to the U.S. Army Corps of Engineers, Contract E86970085, 47 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Raymond, H. L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108(6):505-529.

Seber, G. A. F. 1965. A note on the multiple recapture census. Biometrika 52:249-259.

Sims, C., and F. Ossiander. 1981. Migrations of juvenile chinook salmon and steelhead in the Snake River, from 1973 to 1979, a research summary. Report to the U.S. Army Corps of Engineers, Contract DACW68-78-0038, 31 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Smith, S. G., J. R. Skalski, W. Schlechte, A. Hoffmann, and V. Cassen. 1994. Statistical Survival Analysis of Fish and Wildlife Tagging Studies. SURPH.1 Manual. (Available from Center for Quantitative Science, HR-20, University of Washington, Seattle, WA 98195.)

Williams, J. G., and G. M. Matthews. 1995. A review of flow and survival relationships for spring and summer chinook salmon, *Oncorhynchus tshawytscha,* from the Snake River Basin. Fisheries Bulletin 93:732-740.

g. Facilities and equipment

This project relies mainly on the PIT-tag interrogation systems at dams (and slide-gates at transport dams) and the PSMFC PTAGIS system to provide data needed for survival analysis. As we begin to use the new PIT-tag frequency, we will need to purchase new PIT-tagging equipment compatible with the new tag. Other equipment (boats, vehicles, tanks, tagging supplies, etc.) was purchased in earlier years of this study and will be periodically replaced as needed.

To estimate survival through free-flowing reaches will require use of streambed flate-plate PIT tag detectors to be developed by Project 83-319. Completion of this objective will be dependent on the development of these detectors.

h. Budget

We propose to estimate survival of juvenile salmonids (both yearling and subyearling chinook salmon and steelhead) through a variety of habitats (free-flowing rivers, reservoirs, and dams) over extreamly long distances (from the headwaters in Idaho to the lower Columbia River). A study of this magnitude and scope will require the amount requested in section 5 to acomplish the proposed objectives. The budget is our best estimate of the costs to complete this study; actual amounts needed for each objective will depend on many factors including the numbers of fish PIT-tagged in other studies, successful development of streambed flat-plate detectors, and results achieved in 1999 studies.

Section 9. Key personnel

William D. Muir, Fisheries Research Biologist (Principal Investigator).
B.S. (1977) and M.S. (1991) in Biology, Portland State University. National Marine Fisheries Service, Fish Ecology Division (1978 to present). Coordinates the design, conduct, analysis, and report preparation for the study.

Mr. Muir has worked as a Research Fisheries Biologist for the National Marine Fisheries Service for almost 20 years, working primarily on juvenile salmonid behavior and migration throughout the Columbia River Basin. He has participated in juvenile salmonid research in the Columbia River estuary (distribution, movement, food habits, interactions with other species), at Snake and Columbia River Dams (fish guidance studies, bypass evaluations, behavioral and physiological status of smolts and their effects on fish guidance), at hatcheries (homing studies, photoperiod and temperature manipulation studies and their effect on migration and survival), and most recently on reach survival studies. He began using PIT tags in his research in 1988. He is currently the Team Leader for the Migratory Behavior and Survival group of the Fish Passage Program, Fish Ecology Division.

Recent Publications

Muir, W.D., W.S. Zaugg, A.E. Giorgi, and S. McCutcheon. 1994. Accelerating smolt development and downstream movement in yearling chinook salmon with advanced photoperiod and increased temperature. Aquaculture, 123:387-399.

Muir, W.D., A.E. Giorgi, and T.C. Coley. 1994. Behavioral and physiological changes in yearling chinook salmon during hatchery residence and downstream migration. Aquaculture, 127:69-82.

Muir, W.D., and T.C. Coley. 1996. Diet of yearling chinook salmon and feeding success during downstream migration in the Snake and Columbia Rivers. Northwest Science, 70(4):298-305.

Dr. Steven G. Smith, Statistician
B.S. (1985) in Computer Science, Utah State University. M.S. (1987) in Biostatistics, and Ph.D. (1991) in Quantitative Ecology and Resource Management, University of Washington. National Marine Fisheries Service, Fish Ecology Division (1994 to present). Manages data, performs analyses, writes reports.

Dr. Smith has worked as a Mathematical Statistician for the National Marine Fisheries Service since 1994, during which time his principal responsibility has been management and analysis of PIT-tag data. He was previously a graduate student and then professional staff member at the University of Washington (1987-1994), where he developed statistical models for capture-recapture and computer software (SURPH) to implement them, and helped plan the first two years of the joint NMFS/UW Snake River survival study. Since spring 1995, Dr. Smith has participated in the region's PATH (Plan for Analyzing and Testing Hypotheses) process.

Recent Publications

Kingsolver, J. G. And S. G. Smith. 1995. Estimating selection on quantitative traits using capture-recapture data. Evolution, 49:384-388.

Skalski, J. R., S. G. Smith, R. N. Iwamoto, J. G. Williams, and A. Hoffmann. 1998. Use of PIT-tags to estimate survival of migrating juvenile salmonids in the Snake and Columbia Rivers. Can. J. Fish. Aquat. Sci. 55:1484-1493.

Smith, S. G., J. R. Skalski, W. Schlechte, A. Hoffmann, and V. Cassen. 1994. Statistical Survival Analysis of Fish and Wildlife Tagging Studies. SURPH.1 Manual. (Available from Center for Quantitative Science, HR-20, University of Washington, Seattle, WA 98195.)

Dr. John R. Skalski, Statistician
B.S. (1974) in Wildlife Management/Biology, University of Wisconsin, Stevens Point. M.S. (1976) in Wildlife Science, Oregon State University. M.S. (1978) in Biometry, Cornell University, Ph.D. (1985) in Biometry, Cornell University.

Dr. Skalski has 20 years of experience as a research scientist and professor of biological statistics. His expertise is in the statistical methods of parameter estimation, sampling theory, impact assessment, population dynamics, and mark-recapture theory. Of particular relevance is his experience and expertise in effects assessment on mobile species and the design and analysis of animal tagging studies. He has been chief statistician on accident assessments of major oil spills, design and analysis of impact assessment studies of major energy production facilities, hydroacoustic fish surveys, and fish tagging studies. He has worked on the design and analysis of Columbia River salmonid tagging studies for nine years.

SELECTED PUBLICATIONS

Lowther, A. B., and J. R. Skalski. 1998. A multinomial likelihood model for estimating survival probabilities and overwintering for fall chinook salmon using release-recapture methods. J. Agri. Biol. and Envir. Stat. 3:223-236.

Skalski, J. R. 1998. Estimating season-wide survival rates of outmigrating smolt in the Snake River, Washington. Can. J. Fish. Aquat. Sci.55:761-769.

Skalski, J. R., S. G. Smith, R. N. Iwamoto, J. G. Williams, and A. Hoffmann. 1998. Use of PIT-tags to estimate survival of migrating juvenile salmonids in the Snake and Columbia Rivers. Can. J. Fish. Aquat. Sci. 55:1484-1493.

Skalski, J. R. 1996. Regression of abundance estimates from mark-recapture surveys against environmental variables. Can. J. Fish. Aquat. Sci. 53: 196-204.

Hoffmann, A., and J. R. Skalski. 1995. Inferential population of an individual-based survival model using release-recapture data: Sample size, validity, and power. J. Appl. Stat. 22: 579-595.

Skalski, J. R., A. Hoffmann, and S. G. Smith. 1993. Testing the significance of individual-and cohort-level covariates in animal survival studies. EURING 92. In: Marked Individuals in the study of bird populations, pp. 9-28. S. D. Lebreton and P. M. North (Eds.). Birkhauser Verlag. Boston, MA.

Skalski, J. R., and D. S. Robson. 1992. Techniques for Wildlife Investigations: Design and analysis of capture data. Academic Press. 237 pp.

Section 10. Information/technology transfer

We will provide technical information obtained from this project to researchers, modelers, and managers through annual reports to BPA, peer-reviewed publications, direct response to requests from PATH participants, and through presentations at public meetings. In addition, we will report estimates of survival each year through timely memoranda to interested parties.

Congratulations!